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AGRICULTURE
Pork Industry Branch

MINERALS FOR SWINE

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A. Minerals necessary in swine diets

Minerals are essential for normal growth and reproduction. **They cannot be synthesized by pigs and must be provided in their diets**. The feedstuffs used in swine diets provide some minerals but supplementation with additional minerals either through the use of commercially prepared premixes and/or supplements is usually necessary.

There are over 20 minerals required in the swine diet. Many of these are usually present in adequate quantities in natural feedstuffs. Ten minerals can frequently be deficient and are routinely added to swine diets. These 10 minerals are grouped either as macro (major) minerals or micro (trace) minerals.

Macrominerals	Microminerals
Calcium	Copper
Phosphorus	Iodine
Sodium, Chlorine > Salt	Iron
	Manganese
	Selenium
	Zinc

Macrominerals are required in relatively large amounts and are expressed in grams or as a percent of feed intake. Microminerals are required in much smaller amounts and are usually expressed in terms of part per million (ppm) or milligrams/kilogram (mg/kg).

Each mineral is discussed below. A brief description of its function in the body and deficiency/toxicity symptoms are included. Table 1 lists the clinical signs of deficiency of the various dietary minerals. Table 2 lists the 1988 National Research Council (NRC) mineral requirements of swine diets.

Calcium (Ca)

The primary function of calcium in the body is as a structural component since approximately 99 per cent of the body calcium is found in the bone and teeth. The remaining 1 per cent is found in soft tissue where it assists such functions as blood clotting and muscle contractions.

Cereal grains and plant proteins contain low levels of calcium and therefore calcium supplementation in swine diets is always required. Animal protein sources such as fish meal, meat and bone meal and dried milk products contribute much higher amounts of calcium. Limestone and dicalcium phosphate are common sources of supplemental calcium.

Symptoms of a calcium deficiency include rickets in young pigs, osteomalacia in older pigs, fractured bones and poor growth.

Calcium excesses can upset the desired calcium-phosphorus ratio (1:1 to 1.5:1) and affect the pigs ability to absorb both minerals. This results in impaired bone mineralization, reduced gains and poor feed efficiency. A zinc deficiency can also be induced by high dietary levels of calcium.

Phosphorus (P)

Phosphorus is involved in almost every aspect of metabolism. It plays an essential role in bone formation and skeletal growth. Phosphorus is also an important component of many enzymes involved in energy, protein and fat metabolism.

Phosphorus is present in variable amounts in almost all feedstuffs used by swine. However, about two-thirds of the phosphorus in grains and plant proteins is in the form of phytate, an organic form which is not readily available to swine. For example, the biological availability of phosphorus in barley, wheat and soybean meal has been estimated to be 35 per cent, 48 per cent and 22 per cent respectively. Canola meal has a very high phosphorus content (1.17%) but the availability is also quite low.

Because of the poorer availability of organic phosphorus, swine diets are supplemented with inorganic phosphorus sources such as dicalcium phosphate and monosodium phosphate. The phosphorus in these inorganic sources is close to 100 per cent availability.

Symptoms of a phosphorus deficiency include reproductive failure in sows and gilts, poor growth rates and bone weaknesses, similar to those caused by a calcium deficiency. Effects of too much phosphorus depend on the calcium level in the diet as well as other factors such as the vitamin D level. An excess of phosphorus in relation to calcium can result in increased mineral resorption from bone in young and adult animals and reduced growth in young swine.

Salt (NaCl)

Salt is composed of sodium and chlorine. Sodium is essential for maintaining the osmotic pressure of body fluids, blood pH, heart action and nerve impulse transmissions. Chlorine is involved in ensuring proper fluid-electrolyte balance. It is also used in the production of hydrochloric acid in the stomach.

Grains and plant protein supplements are low in these elements and salt should be routinely added to almost all swine feeds. A level of 0.25 to 0.5 per cent added salt will meet the salt requirements for all classes of swine.

Some farm water supplies may be high in sodium, and its intake from this source can be substantial. Lower salt levels in feeds may be necessary to compensate for this.

A salt deficiency results in reduced feed and water consumption, slow growth rates and unthriftiness. Long term salt deficiency may lead to salt craving and death.

High levels of salt can be tolerated if adequate drinking water is available. When water is restricted, as little as 1 per cent dietary salt has resulted in toxic signs of nervousness, weakness, staggering, convulsions, paralysis and death.

Copper (Cu)

Copper is required for the functioning of various enzymes and aids in iron absorption from the intestinal tract and iron mobilization from stores in the liver.

Most feed ingredients provide some copper, but generally a supplement is necessary. Agriculture Canada, under the 1983 Feeds Regulations, has stipulated that commercially prepared feeds must contain a minimum of 6 mg and no more than 125 mg of copper per kilogram of complete feed. Copper levels in commercial mineral premixes and protein supplements reflect this restriction. Higher levels of copper (125 to 250 mg/kg) have, however, been used to improve growth and feed efficiency of young pigs. Copper sulphate is the most common source of copper in swine diets.

Symptoms of a copper deficiency include anemia, reduced growth, nervous disorders, lack of coordination and defective bone formation.

Toxic symptoms, where copper exceeds 250 ppm, include reduced feed intake, reduced growth, jaundice and death.

A significant time period (3 to 7 weeks) is usually required for the development of chronic copper toxicity and swine appear to be more tolerant of high dietary copper than cattle are.

Iodine (I)

The only known function of iodine is as a constituent of thyroid hormones, which are important in

regulating the metabolic rate, i.e. the rate at which nutrients are digested and utilized.

Iodine is found in many animal feeds but in very small amounts. The exception to this is fish meal. To ensure adequate dietary iodine, small quantities of iodine are added to feed usually through iodized salt. The iodine requirement is met when salt containing 0.007 per cent iodine is fed at a level of 0.25 per cent in the diet. Both inorganic (potassium iodide, sodium iodate) and organic (EDDI) sources of iodine are available for use in feed.

Iodine deficiency is usually seen in the offspring of iodine-deficient sows. Symptoms in the piglets include hairlessness, thickened skin and goitre (enlarged thyroid gland). Most of the piglets are born alive, but are weak and usually die within hours.

Pigs are fairly tolerant of high iodine levels but iodine poisoning has occurred when dietary levels were between 400 and 800 ppm. Growth rate, feed intake and hemoglobin concentration are depressed when iodine intake is excessive.

Iron (Fe)

Iron is required for the production of blood hemoglobin, which carries oxygen throughout the body. At birth, 47 per cent of the iron in the body is associated with blood. After the neonatal period, 70 - 80 per cent of the total iron is found in hemoglobin and other related blood components.

A newborn piglet is prone to anemia induced by an iron deficiency. Pigs are born with low body iron stores and their main source of nutrients, sow's milk, is quite low in iron (about 1 mg/litre). A very fast growth rate during the first few weeks of life increases the need for iron and makes piglets prone to iron deficiency.

Feeding high levels of iron to pregnant and lactacting sows does not effectively increase the iron content of milk. Therefore, unless supplemental iron is provided directly to the piglets within the first 2 to 3 days after birth, an iron deficiency (anemia) is likely to occur.

Although the piglet can absorb dietary iron through its intestine, it is preferable to use injectable iron. A single dose of 150 to 200 mg (iron dextran or iron dextrin) given intramuscularly in the neck area at 2 or 3 days of age will provide adequate iron until piglets are weaned at 3 to 4 weeks and are consuming feed. Injectable iron has a higher availability than dietary iron, so a much smaller quantity is required to maintain a normal hemoglobin level.

Oral iron supplements incude ferrous sulphate, which is an effective supplement with a high iron availability. Ferric oxide is considered an ineffective supplement, while the availability of iron in ferrous carbonate varies depending on its form. However, it is generally less effective than ferrous sulphate. Oral doses may have to be repeated during the preweaning period.

Signs of iron deficiency include small, hemoglobin-deficient red blood cells, pale mucous membranes, chalky skin color in white-skinned pigs, enlarged heart, spasmodic breathing after exercise and decreased resistance to certain bacterial infections.

Anemia caused by iron deficiency seldom occurs in older pigs as their iron requirement decreases. A balanced ration will provide sufficient dietary iron for a mature pig.

Toxicity symptoms have been shown to occur when iron levels in the diet exceed 5,000 ppm. Large doses of iron may cause anorexia, diarrhea, hypothermia, incoordination, convulsions and death. The lining of the gastrointestinal tract is frequently damaged and the absorption of other nutrients is impaired.

Manganese (Mn)

Manganese is necessary for the functioning of a number of enzymes involved in enery and protein metabolism, bone development and reproduction.

Manganese is normally found in adeqaate amounts in commonly used feedstuffs. However, diets are usually supplemented because requirements for optimum swine performance have not been well defined. High levels of calcium, phosphorus and iron in the diet can reduce the absorption of manganese. Manganous oxide and manganous sulphate are the two most commonly used forms in swine feeding.

Deficiency symptoms include impaired growth, lameness, enlarged hocks, crooked and shortened legs, anestrus or irregular estrus, poor mammary development and lactation, and birth of small, weak pigs with an impaired sense of balance.

The toxic level of manganese is many times the requirement. Toxicity symptoms have resulted when rations containing 550 ppm manganese were fed. Symptoms include decreased growth and feed intake, stiffness and a stilted gait.

Selenium (Se)

Selenium is a component of the enzyme, glutathione peroxidase, that protects cell membranes from damage.

Animal feeds may be low in selenium if they are produced from crops grown on selenium deficient soils or acidic soils, which reduce its availability. In Alberta, selenium levels in soils are usually low, producing crops with very low selenium content. The addition of selenium to swine feeds is routine except when feed ingredients have been analysed and shown to contain adequate levels of selenium to meet the animal's needs.

The amount of selenium that may be added to swine diets is regulated by Agriculture Canada and is limited to 0.3 mg supplemental Se/kg of complete feed. Selenium is added to feeds as sodium selenite or sodium selenate.

The adequacy of dietary selenium levels depends, to a great extent, on vitamin E levels. A high dietary level of vitamin E will reduce the level of selenium required. It will not however completely eliminate the need for dietary selenium. Conversely, if natural diets are low in vitamin E, the requirement for selenium increases. Because of the complex vitamin E-selenium interaction, Agriculture Canada states that any feed containing supplemental selenium must also contain added vitamin E at a level to ensure a total content of at least 10 IU Vitamin E/kg in the complete feed.

A selenium deficiency results in white muscle disease (nutritional muscular dystrophy), mulberry heart disease, liver damage, impaired reproduction and sudden death. Mulberry heart disease most commonly occurs in fast-gaining feeder pigs.

Selenium levels greater than 7.5 ppm have been shown to produce toxicity symptoms. These include loss of appetite, poor growth, hair loss, liver and kidney damage, separation of hoof and skin, poor development of embryos and death.

Zinc (Zn)

Zinc is an important part of many enzyme systems and is a constituent of the hormone insulin.

The concentration of zinc is low in grains and plant protein supplements. It is also associated with phytate and is poorly available to swine. Zinc is commonly added to swine feeds in the form of zinc oxide. High levels of dietary calcium (over 1%) will reduce zinc absorption and increase the pig's requirement for zinc.

A zinc deficiency results in loss of appetite, poor growth, reduced litter size and impaired sexual development in boars. A zinc deficiency also results in a skin condition called parakeratosis.

The skin reddens and eruptions occur, with a dark, watery fluid being secreted. Scabs develop. In borderline deficiencies, a fading of hair color may occur.

The addition of 4,000 ppm of zinc oxide to swine diets did not result in zinc toxicity. The addition of 2,000 ppm of zinc carbonate did, however, result in toxicity within 5 weeks.

Excess zinc results in symptoms including growth depression, inflammation of the gastrointestinal tract, arthritis and internal hemorrhages.

B. Mineral requirements and allowances

The estimated requirements (National Academy of Sciences, National Research Council 1988) of the various classes of swine are shown in Table 2. It can be seen that requirements are highest for young pigs and lactating sows, and are lower in growing swine.

Recommended levels of macrominerals in the diet and of trace minerals to be added to the diet are shown in Table 3. Since lactating sows and young pigs have the highest requirements, it is suggested that a single premix be used for all classes of swine but that the incorporation rate be halved for growing and finishing pigs.

Allow a smaller safety margin for minerals than for vitamins, to avoid possible toxicities. The suggested total levels of calcium and phosphorus are slightly higher than the requirements to avoid any possible shortfall in one or more ingredients, and to allow for some flexibility in feeding, e.g. limit feeding. This need for flexibility is particularly important with dry sows. An incorporation rate of 0.4 per cent to 0.5 per cent iodized salt is suggested for all types of swine feed, but this can be cut back to half that amount if the main protein supplement used is meat meal or if the water supply is salty.

Table 1. Swine mineral chart (from NRC 1988)

Mineral	Clinical signs of deficiency (includes some necropsy findings)
Calcium	Rickets in young animals Osteomalacia in mature animals Low calcium tetany Weak bones Elevated blood inorganic phosphorus Low blood calcium
Phosphorus	Poor growth Rickets in young animals Weak bones Low blood inorganic phosphorus Elevated blood calcium
Sodium	Poor growth Poor appetite Low water consumption Elevated blood potassium Salt craving, e.g. drinking urine
Chloride	Poor growth Low blood chloride
Iron	Poor growth Rough hair coat Pallor (paleness) Anemia
Copper	Leg weakness Lameness Ataxia (nervous symptoms) Anemia Reduced blood copper
Iodine	Enlarged thyroid gland (goitre) Weakness, hairlessness in newborn pigs Thick, pulpy skins — cretinism in young — myxedema in adults
Zinc	Poor growth Poor appetite Paraketosis (rough, reddened, thick spotty skin)
Manganese	Lameness in growing pigs Crooked and shortened legs in young pigs Disturbed estrus cycles Small, weak pigs at birth Poor mammary development Poor milking ability
Selenium	Edema (fluid in tissues) Sudden death White muscle disease (pale bands in muscle) Mulberry heart disease (degenerated heart) Liver necrosis

Table 2. Mineral requirements of swine (% or milligrams/kg diet) (Nutrient Requirements of Swine, 1988)

	Growing - finishing swine (liveweight, kg)[1]					Bred gilts,[2] sows, and adult boars	Lactating[3] gilts and sows
	1 - 5	5 - 10	10 - 20	20 - 50	50 - 100		
Calcium (%)	0.90	0.80	0.70	0.60	0.50	0.75	0.75
Phosphorus, total (%)*	0.70	0.65	0.60	0.50	0.40	0.60	0.60
Phosphorus, available (%)	0.55	0.40	0.32	0.23	0.15	0.35	0.35
Sodium (%)	0.10	0.10	0.10	0.10	0.10	0.15	0.20
Chlorine (%)	0.08	0.08	0.08	0.08	0.08	0.12	0.16
Magnesium (%)	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Potassium (%)	0.30	0.28	0.26	0.23	0.17	0.20	0.20
Copper (mg)	6.00	6.00	5.00	4.00	3.00	5.00	5.00
Iodine (mg)	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Iron (mg)	100.00	100.00	80.00	60.00	40.00	80.00	80.00
Manganese (mg)	4.00	4.00	3.00	2.00	2.00	10.00	10.00
Selenium (mg)	0.30	0.30	0.25	0.15	0.10	0.15	0.15
Zinc (mg)	100.00	100.00	80.00	60.00	50.00	50.00	50.00

[1] Based on ad libitum feeding
[2] Based on a daily feed intake of 1.9 kg
[3] Based on a daily feed intake of 5.3 kg

At least 30 per cent should be provided from non-plant sources.

Table 3. Suggested total mineral levels in swine diets

Mineral/units	Creep	Starter	Grower	Finisher	Nurse sow	Pregnant sow
Calcium (%)	0.95	0.8	0.7	0.6	0.9	0.9
Phosphorus (%)	0.75	0.65	0.6	0.5	0.7	0.7
Iron (ppm)	150	150	150	150	150	150
Manganese (ppm)	20	20	12	12	12	12
Zinc (ppm)	120	120	100	100	120	120
Copper (ppm)	125	125	20	20	20	20
Iodine (ppm)	0.2	0.2	0.2	0.2	0.2	0.2
Selenium (ppm)	0.3	0.3	0.3	0.3	0.3	0.3

C. Mineral Sources

The mineral composition of feedstuffs commonly used in swine diets is shown in Table 4.

The common sources of calcium and phosphorus for adding to swine diets are limestone (calcium carbonate), dicalcium phosphate, and defluorinated rock phosphate. Sterilized bone meal is another source of these minerals.

Rock phosphate also contains a high level of salt (sodium chloride). Salt is generally added to feeds as iodized salt, and sometimes as cobalt-iodized salt.

The mineral composition of the common mineral sources is shown in Table 5.

D. References

National Research Council, *Nutrient Requirements of Swine*. National Academy Press, Washington, D.C. 9th revised edition, 1988.

Pond, W.G. and J.H. Maner. *Swine Production and Nutrition*. AVI Publishing Company Inc. Westport, Connecticut. 1984.

Ullrey, D.E. and J.C. Rea. *Minerals for Swine, Pork Industry Handbook*, West Lafayette, Indiana.

Table 4. Average mineral composition of feed ingredients commonly used in swine diets on an as fed basis. (Nutrient Requirements of Swine 1988)

	% of diet					
	Ca	P	Na	Cl	Mg	K
Barley	.05	.34	.03	.11	.13	.46
Wheat	.04	.37	.02	.05	.12	.43
Corn	.03	.28	.01	.05	.11	.33
Oats	.08	.34	.05	.09	.14	.40
44% Soybean Meal	.30	.65	.04	.04	.29	2.11
47.5% Soybean Meal	.26	.64	.01	.04	.30	2.13
Canola Meal	.68	1.17			.64	1.29
Field Peas	.12	.41	.04	.05	.12	1.01
Alfalfa Meal	1.40	.23	.10	.47	.29	2.40
Bran	.13	1.16	.05	.05	.57	1.20
Beet Pulp	.62	.09	.18	.04	.25	.20
Dried Skim Milk	1.28	1.00	.57	.90	.12	1.60
Dried Whey	.86	.76	1.30	1.50	.13	1.10
Fish Meal (herring)	2.20	1.67	.59	.99	.14	1.10
Meat Meal (55%)	8.27	4.10	1.15	.91	.27	.55

	mg/kg diet				
	Cu	Fe	Mn	Se	Zn
Barley	8	73	16	.16	17
Wheat	5	35	30	.29	35
Corn	4	33	6	.07	19
Oats	6	64	36	.21	35
44% Soybean Meal	23	140	31	.10	52
47.5% Soybean Meal	20	131	37	.10	57
Canola Meal	10	159	54	1.00	71
Field Peas	6	65	3	0.10	23
Alfalfa Meal	10	404	31	.33	19
Bran	11	145	115	.64	95
Beet Pulp	13	266	34		1
Dried Skim Milk	11	8	2	.12	39
Dried Whey	47	169	6		3
Fish Meal (herring)	6	114	5	1.95	125
Meat Meal (55%)	10	441	9	.40	80

Information prepared by:

Dr. R. Blair
Department of Animal Science
University of British Columbia, and

Karen Dupchak
Animal Nutritionist
Manitoba Agriculture

Reviewed and revised by:

Sam Jaikaran
Mongastric Nutritionist
Alberta Agriculture

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Table 5. Main Minerals Contributed by Common Mineral Sources Used in Swine Diets.

Mineral Source	Formula	Content of material %†
Calcium and Phosphorus		
Ground limestone	$CaCO_3$	Calcium 38
Calcium carbonate	$CaCO_3$	Calcium 40
Dicalcium phosphate anhydrous	$CaHPO_4$	Phosphorus 22.8
Dicalcium phosphate dihydrate	$CaHPO_4$ $2H_2O$	Calcium 23.3 Phosphorus 18
Tricalcium phosphate	$Ca_3(PO_4)_2$	Calcium 38.8 Phosphorus 20
Defluorinated rock phosphate		Calcium 32 Phosphorus 18
Sterilized bone meal		Calcium 24 Phosphorus 12
Copper		
Cupric sulfate	$CuSO_4$	Copper 39.8
Cupric sulfate pentahydrate	$CuSO_45H_2O$	Copper 25.5
Cupric chloride	$CuCl_2$	Copper 47.3
Iodine		
Calcium iodate	$Ca(IO_3)_2$	Iodine 65.1
Potassium iodide	KI	Iodine 75.5
EDDI		Iodine 79.5
Iron		
Ferrous sulfate heptahydrate	$FeSO_47H_2O$	Iron 20.1
Ferrous acetate tetrahydrate	$Fe(C_2H_3O_2)_24H_2O$	Iron 22.7
Ferrous Carbonate	$FeCO_3$	Iron 48.2

Mineral Source	Formula	Content of material %†
Manganese		
Manganous oxide	MnO	Manganese 77.4
Manganous dioxide	MnO_2	Manganese 63.2
Manganous carbonate	$MnCO_3$	Manganese 47.8
Manganous chloride tetrahydrate	$MnCl_24H_2O$	Manganese 27.8
Manganous sulfate	$MnSO_4$	Manganese 36.4
Manganous sulfate hydrate	$MnSO_4H_2O$	Manganese 32.5
Manganous sulfate tetrahydrate	$MnSO_44H_2O$	Manganese 24.6
Selenium		
Sodium selenite	Na_2SeO_3	Selenium 45.7
Sodium selenate	Na_2SeO_4	Selenium 41.8
Sodium and Chloride		
Sodium chloride (salt)	NaCl	Sodium 39.4
Zinc		
Zinc carbonate	$ZnCO_3$	Zinc 52.1
Zinc chloride	$ZnCl_2$	Zinc 48
Zinc oxide	ZnO	Zinc 80.4
Zinc sulphate	$ZnSO_4$	Zinc 40.5
Zinc sulphate hydrate	$ZnSO_4H_2O$	Zinc 36.4

† Except for limestone, assumes 100% purity. Content may be different in technical grades.